Interview with David Moore

Allan Rossman
California Polytechnic State University

E. Jacquelin Dietz
Meredith College

David Moore
Purdue University

Journal of Statistics Education Volume 21, Number 2 (2013),
www.amstat.org/publications/jse/v21n2/rossmanint.pdf

Interview with David Moore

David Moore is Professor Emeritus of Statistics at Purdue University. He served as the first President of the International Association for Statistical Education (IASE) from 1993-1995 and as President of the American Statistical Association (ASA) in 1998. He is a Fellow of the ASA and of the IMS and was awarded the ASA's Founders Award in 2001. He has written several influential, widely used textbooks for introductory statistics.

This interview took place via email on May 3, 2013 – June 12, 2013.

AR: This issue marks the 20th anniversary of the Journal of Statistics Education. *The very first issue of* JSE *featured an interview of Frederick Mosteller conducted by David Moore. To commemorate this, I am extremely privileged not only to be interviewing David for this issue but also to be joined in conducting this interview by Jackie Dietz, the Founding Editor of* JSE. *Thanks very much to you both.*

Twentieth Anniversary of *JSE*

JD: Hi, David. Thanks so much for agreeing to this interview on the occasion of the 20th anniversary of JSE. *I'm especially pleased to celebrate this occasion with a second interview involving you, this time as the subject rather than the interviewer. To set the stage for the founding of* JSE *and the changes in statistics education that have occurred since then, could you describe the state of statistics education twenty years ago, at the time that you interviewed Frederick Mosteller?*

DM: Let's begin with some context. I received my Ph.D. in 1967, toward the end of an era when it was fashionable for statistics researchers to be as much like mathematicians as possible. The world changed rather rapidly, especially after about 1980, as statistics moved back toward its roots in scientific inference and analysis of data. The change was driven by the revolution in computing, and neither that revolution nor the pace of change in statistics research has slowed. Where research led, graduate education followed. The paradigm Ph.D. program today is quite different from that of the 1960s. Mathematics remains important, but the tool set for a student writing a thesis on "Annotation-Informed Integration of 'omic Data in Next-Generation Sequencing" or "Divide and Recombine (D&R) for the Analysis of Large and Complex Data Sets with Application to VOIP" extends to lots of biology in the first example and what my Purdue colleague Bill Cleveland calls "algorithmic thinking" in the second. (Those are the titles of two recent Ph.D. theses in the Purdue Statistics Department.)

Our topic, however, I take to be statistics education for undergraduates (majors or not) and perhaps secondary school students. Here I must say that little of real substance has changed in the past 20 years, the 1997 advent of AP Statistics being the most significant exception.

In the mid-1990s, there was: recognition that the undergraduate student body nationally was broader and perhaps less well prepared than in the past; a consensus that colleges and universities were becoming unaffordable, so that major economies in teaching methods were needed; a growing reform movement that deemphasized lecturing in favor of diverse types of structured student activities; and an expectation that technology would soon bring about major changes in our teaching. Look back at the discussion in "Statistics education fin de siècle" (Cobb, Garfield, Meeker, and Moore 1995) for a glimpse of the mid-1990s atmosphere. *This article could have been written yesterday!* Fred Mosteller, in our 1993 conversation, described the promise of new technology (television) at the time of Continental Classroom in the 1960s, and the reasons that promise was not widely realized. His comments apply with minor changes to the issue of MOOCs today. Going back yet further into the dark ages, Harold Hotelling devoted much of an article on "The teaching of statistics" (Hotelling 1940) to the concern that statistics was taught in multiple academic departments, often by instructors not fully educated in statistics and not aware of recent advances. (He included mathematics departments among the offenders.)

JD: I just reread "Statistics education fin de siècle," and I must agree that much of the article feels very current today! But I do think I have seen some big changes in the teaching of statistics over my career. Last fall I was asked to present a talk on an education-related topic and I chose the title "JSE, AP Statistics, and Randomization Tests in Stat 101 – 30 Years of Change in Statistics Education." So we agree that the introduction of AP Statistics was a notable

development in statistics education. Another topic in my talk was the role of JSE *and other new publication outlets in the development of statistics education as an academic discipline and research area. There are now multiple journals, academic programs, and large numbers of Ph.D. dissertations dedicated to teaching statistics and statistics education research. Do you think these developments have had an impact on the conflict between research and undergraduate teaching that you wrote about in "Statistics education fin de siècle"?*

DM: Let me start by saying that I would be very encouraged if Stat 101 at most institutions did in fact mention permutation tests and other resampling methods. This isn't the case, and the failure of intro courses to keep up with advances in practice is one reason for my feeling that little of substance has changed. The introduction and quite rapid growth of AP Statistics is notable. We might ask whether colleges and universities have taken advantage of this in ways other than awarding credit to incoming students with scores of 4 or 5, say by offering a suitable second course that builds on the AP curriculum. The recently published *STAT 2* (Cannon et al. 2013), by a group of my favorite people, is one avenue, and even presents a bit on resampling procedures.

It is certainly encouraging that statistics education now gets more attention at the graduate and research level. This trend was just starting twenty years ago. Prior to that time, just as statistics was once often wrongly thought of as a subfield of mathematics, statistics education was hidden within mathematics education and was in fact more often concerned with probability than with data-oriented statistics. But we must ask whether this development has impacted undergraduates studying statistics. As far as I know (do remember that I have now been retired for 8 years), it has not. Undergraduate statistics is still taught in multiple academic departments, certainly more often by trained statisticians than in Hotelling's day, but my sense is that the proportion of undergraduate statistics taught by people trained in statistics education is about the same as the proportion of undergraduate mathematics taught by people whose primary scholarly interest is mathematics education. At least in research universities, this proportion is roughly zero. "Mathematics" and "Mathematics Education" are regarded as different fields, and those who live in the former do not greatly respect the latter. Faculty in both fields must publish, in journals of their own field, and both feel the continuing tension between doing publishable scholarly work and undergraduate teaching.

If I may be autobiographical for a moment, in the last third of my career I concentrated on statistics education (my last statistics research paper appeared in *JASA* in 1989). It often struck me that I was writing and speaking on statistics education, and was even regarded as an authority, with essentially no background in education research. My audience was statisticians and teachers of statistics, and in some cases, such as the *American Mathematical Monthly* papers with George Cobb (Cobb and Moore 1997, 2000), mathematicians. To this audience, my credentials in statistics proper seemed more important than my lack of credentials in education. I suggest that readers assess the significance of the emergence of statistics education as a field by asking themselves if this remains true.

JD: Twenty years ago when we first discussed the founding of a new journal, we argued that the lack of publication outlets for work on statistics education discouraged faculty from investing time and effort in the scholarship of teaching and learning statistics. We believed (or at least we

hoped) that JSE *would encourage scholarly work that would ultimately lead to the improvement of teaching.* JSE *has not only survived, but has flourished – recent issues often contain twice as many articles as in the early years. I'd like to think that the persistence and growth of* JSE *are indicators of at least two positive developments – first, that there is tremendous interest in improving the teaching of statistics and, second, that writing articles about teaching statistics is increasingly seen as a valid professional activity. Am I too optimistic?*

DM: The growth of *JSE* is certainly a good thing. To what extent it is an indicator of other positive trends I am unable to say. Interest in improving teaching depends on personal and institutional priorities, and has always varied greatly across people and institutions. In the absence of data, I simply don't know how much this interest has grown. Similarly, incentives for research and writing about teaching, in any discipline, vary so much among institutions that it is hard to see an overall pattern. I do believe that the number of people who think seriously about improving the teaching of statistics has grown. Interest in science education more broadly has certainly increased. For example, *Science* has published annual issues devoted to science education since 2009. It would be surprising if statistics were not a participant in this broader trend.

It is time, I think, to point to two other trends that have taken off in the 20 years since my conversation with Fred Mosteller. At least in large universities it is now common for undergraduate service courses to be organized and supervised by non-tenure-track teachers with titles such as "continuing lecturer." These teachers, unlike the adjuncts whose employment is so often deplored, have continuing appointments and are at least semi-permanent members of their academic department. We might regret that tenured and tenure-track faculty have less contact with large service courses, but on the other hand we now have a group of professionals whose sole focus is teaching and who have an incentive to improve at least the efficiency of teaching large groups of students. Credentials vary (often an M.S. in statistics). I don't sense that these teachers are much involved in the "*JSE* community." Is that correct? If so, can we improve this situation?

The second trend is that many, probably most, large undergraduate courses now have a substantial online component. Introductory texts routinely offer an array of online features, from ancillaries up to completely online versions. Teachers, in particular the continuing lecturers whom I mentioned, often devote considerable effort to the online side of their courses, many of which even allow students to complete the course without attending class. The spread of online education is a real boon to mature and disciplined students – for example, my daughter recently received a Master's degree from the University of Cincinnati which she did entirely online while living overseas. For less mature students, motivation and guidance are provided by arrangements that allow students to choose a mix of classroom and online, with access to live instructors in office hours and other settings. Are these arrangements designed with attention to the reform goal of increasing student activity relative to passive information transfer? More generally, do they pay adequate attention to effective instruction, as opposed to efficiency and flexibility? I see surprisingly little in *JSE* about these increasingly common "mixed-mode" course designs.

JD: I agree that you've identified two important trends in statistics education. I know that in recent years several universities have advertised tenure-track positions in statistics education

within their Departments of Statistics. But, as you say, there are also many universities with non-tenure track teaching specialist positions, including NC State, Ohio State, and the University of Georgia. I know faculty both with and without Ph.D.s who hold such positions, and some of them actually are very active in the statistics education community, including involvement with JSE.

A quick search of the JSE *archive yielded six articles with "online" in the title and two with "hybrid" (meaning a mix of online and face-to-face instruction). An equally quick search of the program for the recent United States Conference on Teaching Statistics (USCOTS 2013) turned up five poster presentations, four breakout sessions, and one exhibitor demonstration about teaching online, hybrid, or "flipped" courses. In a "flipped" or "inverted" course, much of the content is delivered outside of class, often online, so that class time can be devoted to activities and group problem-solving. Does that strike you as a promising approach for teaching statistics?*

DM: Hmm. Six articles in twenty years with "online" in the title strikes me as relative neglect of what is certainly the most visible trend in at least the mechanics of teaching. What is the value of a live teacher? Motivating students and generating discussion through personal interaction may be the roles in which a live teacher is most effective relative to other modes of instruction. Delivering content can mostly be automated, especially if a good deal of interaction and student activity is built in. But there is no substitute for the encouraging presence of a sensitive teacher for students who are poorly prepared, lacking in self-confidence, and perhaps not strong in self-discipline. That is, the effectiveness of online or computer-based instruction (once we advance beyond routine drill) tends to increase as the maturity and preparation of students increases. Guiding problem-solving and structuring discussions – compare the level of unstructured online chat – are also roles for human teachers. All of this suggests that flipped courses are in general a good idea, as they apply the scarce and expensive time of live teachers to greatest advantage. I do worry about weaker students getting lost without more intense and personal interaction. Of course, these students are at risk in traditional large lecture courses as well, so this is not a criticism of new modes.

Tuning Neurons

AR: Your mentioning of what live teachers can do best brings to mind the presentation that you gave, and subsequent article that you wrote (Moore 1995) when you received the Mathematical Association of America's Haimo Award for Distinguished Teaching. Your theme and title for that article were "The Craft of Teaching." How did you come to choose that theme?

DM: Faculty in research universities who care about teaching often muse about the varied performance of their colleagues. I wanted to emphasize that good teaching rests on a collection of learned skills rather than on charisma, extroversion, or natural flair. A corollary is that anyone can learn to be a competent teacher. Faculty who teach poorly are almost always simply being irresponsible and should be called to account. There is in this respect nothing unique about teaching. Most professions are at root crafts. Here, for example, is the chef André Soltner: "I always say this to the young chefs, and mean it: The customer is excited, he says you are an artist but we are not, just crafts people with a little talent. If the chef is an artist, he doesn't succeed.

Why? Because he is inspired today but not tomorrow. We cannot do that. We have to serve the customer when he's here. He doesn't come back tomorrow." Understanding that we teachers are craftspeople reminds us that we have an obligation to do our work with competence.

AR: That article of yours contains a delightful line that I have repeated often myself: "Nothing tunes the neurons like a little disagreement." Have you received much disagreement from your contention that teaching is a craft?

DM: No. This may be because few read the article (which, by the way, remains one of my favorites). Or because it appeared before the era of warring blogs and counter-blogs. Or because the power of confirmation bias led those who disagree to simply ignore contrary data. (I did cite data – and I did receive a few compliments, no doubt also reflecting confirmation bias). I like Kahneman's *bon mot,* "Nothing in life is quite as important as you think it is while you are thinking about it" and extend it to remind myself that nobody else thinks what we write is as important as we imagine it to be.

AR: While it's probably true that others do not think this interview is as important as I imagine it to be, I want to ask about two other presentations/articles of yours that I suspect have generated some disagreement over the years. You participated in a session organized by former JSE *editor Tom Short at the 1996 Joint Statistical Meetings, addressing the question of whether Bayesian ideas and methods should be taught in introductory statistics courses. Your fellow presenters in the session, Don Berry and Jim Albert, argued in the affirmative, while you expressed strong reservations and reasons to hesitate. Your presentation was developed into two articles (Moore 1997a; Moore 1997b). I think it's fair to say that the use of Bayesian methods has grown since then, but it's still the case that very few introductory courses present a Bayesian approach to statistics. Would you present a summary of your argument against teaching Bayesian ideas in introductory courses, and has your position on this issue changed at all?*

DM: Well, Allan, if you are hoping I will say something that generates disagreement, you have chosen the right issue. It's true that the use of Bayesian methods has increased, but outside the high-expert stratum, much of this use involves some variety of "automatic Bayes" with off-the-shelf priors not customized to the actual situation. I have a low opinion of this kind of cop-out. (Traditional "frequentist" inference procedures are – at least in skilled hands – not applied automatically. They are preceded by data analysis to ascertain their applicability.) It's also true, I think, that the use of resampling methods has increased even more than the use of Bayesian methods – and I will repeat that I think these methods *should* appear in introductory courses. Note that both Bayes and resampling depend on good software. This is a big reason why both have been avoided in teaching beginners. Readers interested in interplay between Bayes and resampling, as well as in opinions better founded than mine in a mastery of both fields, should look up recent work of Brad Efron. One final preliminary: like most statisticians, I'm eclectic. There are clearly situations that call for a Bayesian approach. Bayesians tend to think (wrongly, in my opinion) that *all* problems are nails for their hammer to pound. This is the last remnant of the dream of systematizing inference from uncertain empirical data, a dream that in the guise of decision theory kept statistics overly close to mathematics in my grad school days.

To turn to your specific question, the *American Statistician* paper (Moore 1997a) you cite is easily available and presents at length views that I still hold, along with interesting discussion. I cited *data* from several applied fields showing that the impact of Bayesian methods in practice was vanishingly small, despite their prominence in statistical journals. More current data might show a different pattern, though I suspect that replacing "vanishingly small" by "small" would be an adequate update. In that case, the opportunity cost of displacing more widely used methods from the syllabus of a first course remains. I would of course prefer to use any spare niches to introduce resampling, which fits better in a data-oriented introduction and is an excellent vehicle for understanding the reasoning of traditional inference.

I will not attempt to summarize my discussion of why Bayesian reasoning is much more subtle than at first appears (outline in Moore 1997a; details in Moore 1997b), in favor of quoting two paragraphs from the end of the *American Statistician* paper:

> "What do we want our students to learn? In our more realistic moments, we recognize that *many students will not take away from our first courses any clear conceptual grasp of formal probability or of the more subtle varieties of inference.* I would place all flavors of hypothesis testing and all Bayesian reasoning in the 'more subtle' category. Students will, if we provide the opportunity, take away a number of messages more valuable than a grasp of formal inference. ...
>
> Here are some things I want my beginning students to learn. *First, look at your data*, starting with graphs and simple calculations. Look for overall patterns and for deviations such as outliers. Always ask what your data say in the context of the setting they describe. *Recognize the importance of data production*. Faulty data production (e.g., voluntary response or confounding) can render data worthless in ways that no fancy analysis can rescue. Understand that an observed association does not imply causation, and that randomized comparative experiments are the gold standard for evidence of causation. *Randomness*, as exemplified by deliberate use of chance in designs for data production, produces regular patterns of long-run behavior described qualitatively by the law of large numbers and the central limit theorem. This regularity applies *only* in the long run. *The data take priority over any model* (such as a normal distribution or a linear relationship) used to analyze them. Analysis starts by looking at the data, and models and assumptions are judged by the data. 'Data sense' might summarize my primary objectives for a first statistics course."

"Priority to data rather than models" is a pretty good summary of why I am dubious about introducing Bayesian methods in a first course for general students.

AR: Thanks, David. I'll only add as a brief follow-up that at the recent USCOTS, George Cobb predicted that introductory courses will keep moving toward simulating randomization tests for assessing significance, but will also begin moving toward Bayesian intervals for estimating effects. George referred to the distinction that Dempster makes between two types of questions: IS questions ("is there an effect?") that depend on model selection and lend themselves to

Fisherian testing, and IT questions ("how big is it?") that take the model as given and lend themselves to a Bayesian approach (Dempster 1971).

You're welcome to comment on George's prediction, of course, but I want to ask next about another article in which I believe you set out to be deliberately provocative: "Should Mathematicians Teach Statistics?" (Moore 1988). You left the reader in no suspense about your answer to this question, as your first word in the article contained two letters followed by an exclamation point. How did you come to write that article, what was your primary goal, and what kind of responses did you receive?

DM: Warren Page, editor of MAA's *College Mathematics Journal*, invited the article as part of a "forum" series designed to stimulate discussion. The 5-page article is followed by 24 pages of responses and my 2-page reply. (Additional responses sent by readers appear in the following issue of the journal.) The responses are fascinating in part because 1988 is long enough ago that the responders come from the generation of statisticians and teachers before me as well as from my own generation. The article, as you suggest, is deliberately "rhetorical and not wholly sincere," as I say in my reply, and the responders present important caveats. Do note the strong support from the non-academic statisticians and Fred Mosteller's thoughtful invocation of the leading role of mathematically trained scholars in "great jumps" in the field of statistics.

You and Jackie have now mentioned a number of articles by me and others. So I should note that all of these are available in JSTOR. JSTOR started in 1995, and has grown to be a major resource, archiving 72 statistics journals, 2171 in science and mathematics overall, and many more in other fields. JSTOR may deserve to be listed among the significant changes in education since the mid-1990s: a university library on your screen. Want an example of regression in anthropology? JSTOR is searchable.

In response to George's prediction, I'm not up on these trends, so I will make only brief comments. First, while the results of applying classical and Bayesian methods tend to be similar in estimation problems, they often diverge dramatically in testing situations. Bayesians detest *P*-values. Does the trend that George refers to amount to favoring Bayesian methods when the choice of approach doesn't matter and classical methods when it does? And how many real-world problems allow us to truly "take the model as given"?

Textbook Writing

JD: David, I'd like to turn now to some questions about your textbooks. I used Statistics: Concepts and Controversies *for a course I taught for over two decades at NC State, and I've used both* The Basic Practice of Statistics *and* Introduction to the Practice of Statistics *during my nine years at Meredith College. How did your career as a textbook writer begin?*

DM: This is a somewhat convoluted tale. The Annenberg Foundation and the Corporation for Public Broadcasting had a joint project that funded educational television, focusing on college-level telecourses. COMAP, the Consortium for Mathematics and its Applications, a Boston-area nonprofit that produces innovative educational materials in the math sciences, won a grant from the Annenberg-CPB project for a telecourse in liberal arts mathematics that had a modeling

rather than a pure math flavor. (This course was eventually titled *For All Practical Purposes*.) One module was to cover statistics and probability. Fred Mosteller recommended me as the content person. The module turned out well, so Annenberg-CPB invited proposals for a telecourse on introductory statistics. It was clear who had the inside track: COMAP won the grant, with me as the content developer. The result was *Against All Odds*, which appeared in 1989.

Doing a telecourse was fascinating, and very time-consuming. I did not think that standard intro stat courses offered a contemporary picture of the discipline – next to nothing on data production, no systematic presentation of data analysis, outdated inference procedures such as the version of two-sample *t* that requires equal population variances, and so on. So I outlined what I thought was a more modern course, then outlined 26 half-hour TV programs. The expert producers located the kinds of examples I had specified for vignettes to be shot on location. I drafted scripts, the producers came back with revisions that fit the required timing, the on-location vignettes were shot and edited (a 5-minute segment starts with half a day's shooting), more revisions, and so we went cyclically on. As far as I know, the revisions introduced only one error, when the producers had to save a few seconds and made a last-minute change in wording that they thought did not change the meaning. It is now hard to recall that the late 1980s were still the dark ages for graphics. TV was analog, computers were digital, and there was no interface. I made computer-generated plots at Purdue, a sequence of plots for animated graphics, and mailed them to Boston. An artist then used a $150,000 machine (donated) intended for making analog TV graphics to render my intentions. This machine could not accept as input either equations or my hardcopy graphics. The graphics in *Against All Odds* are primitive by contemporary standards. The vignettes shot on location (it's expensive to fly camera crews around the country) are harder to replace, and some of them are still excellent.

Even a telecourse requires a text. The Annenberg-CPB contract required that the text be ready before the telecourse was released so that potential users could see what was coming. I drafted my Purdue colleague George McCabe, a very accomplished applied statistician, and we wrote *Introduction to the Practice of Statistics.* There was no time for class testing and little time even for reviews. So the book was written under considerable time pressure. Because of this, and because *IPS* broke with the then-standard profile of first courses, I was a bit surprised by its success. *IPS* was quickly adopted by quite a few leading statistics departments, and its use spread from that base.

AR: Like Jackie, I've also taught with Statistics: Concepts and Controversies *many times over the years. That book came before IPS and BPS, right? How did you come to write it?*

DM: Yes, *SCC* appeared in 1979. It originated in pure departmental necessity. The Purdue Statistics Department in those days was, in the eyes of the administration, short of undergraduate student count. Looking around, it appeared to me that the Mathematics Department was doing a poor job in offering courses that would satisfy the quantitative requirement of the College of Liberal Arts. Algebra for all seemed to be their motto. So I invented a course, which soon became our largest, and after 6 years turned it into a text. The idea was to ask entering liberal arts students to read, write, and think while introducing them to statistical ideas important to any broadly educated citizen and surreptitiously building their basic math skills without repeating

high school. This was a bit idealistic, as it turned out that first-year students with weak math skills were also weak in reading, writing, and thinking. Nonetheless, I think that the course and the text serve a useful purpose. By the way, SCC and the excellent *Statistics* by Freedman, Pisani, and Purves (2007) appeared almost simultaneously, and independently arrived at many similar emphases. FPP is a more sophisticated book, which reflects the difference in preparation between entering liberal arts students at Berkeley and Purdue.

JD: Your comments have made me think about the role of inference in the first course. When I used SCC at NC State, I didn't include the chapters at the end on confidence intervals and hypothesis tests. I now use IPS at Meredith for our first course for non-math majors, and although I include formal inference, it makes up a small part of the course. So I have long believed that there are many topics more important to include in the first course than formal inference. But now, there is a lot of excitement in the statistics education community about teaching inference using resampling methods. That approach allows inference to be introduced early in the course and provides a unified approach to inference for many parameters. If technology were available to teach inference using resampling methods, would you advocate a more central role for inference in the first course?

DM: I also omitted inference (other than a verbal presentation of the idea of statistical significance) when teaching entering liberal arts students from *SCC*. And I of course agree that data analysis and data production are so important that a reduction in the once-standard emphasis on probability and probability-based inference is wise. But if we are presenting an introductory course in statistical methods (that is, not a concepts course as in *SCC*), I favor a balanced introduction to data analysis, data production, and inference that includes both the reasoning of significance tests and confidence intervals and a detailed presentation of some basic procedures. This will include discussion of robustness and of how to assess in practice the requirements for inference. I support using resampling methods to introduce inference, with caveats, but this in itself does not increase the overall emphasis on inference at the expense of data analysis and data production.

The most important advantage of introducing inference via resampling, rather than via the sampling distributions of simple statistics, is that the basic reasoning is clearer. This is particularly true when testing is approached via permutation tests. Moreover, students should have learned how to look at distributions (shape, center, spread) in their introduction to data analysis, and these same skills apply to looking at permutation or bootstrap distributions. It is also possible to avoid a discussion of the theoretical sampling distribution of $\bar{x}$ or $\hat{p}$, a discussion that in the case of $\hat{p}$ requires learning about a somewhat awkward and not very accurate approximation to the true sampling distribution.

Now for the caveats. The basic bootstrap percentile confidence interval, while intuitive, is often not very accurate. The refinements (e.g., bias-corrected accelerated, BCa) that produce intervals that are accurate in a wide variety of settings are quite technical and in a first course must be left to the magic encoded in the software. This doesn't bother me – we happily allow software to give us *P*-values and much else without discussing the algorithms behind the output. But BCa or other accurate bootstrap intervals imply use of professional software rather than the simple, even do-it-yourself, software that can handle basic resampling. Are the masses ready for *R*?

Permutation tests come with important restrictions on the settings in which they can be applied, due to the need to resample in a way "consistent with the null hypothesis." This is perplexing for beginners. Moreover, I do think we have an obligation to introduce students to the procedures they are most likely to meet in reading studies in their field of application. So we cannot avoid e.g. the *t* procedures. It is possible to present *t* procedures as formula-based approximations to resampling procedures. This works well because *t* is quite robust. For a long time, I was in the habit of doing both a *t* and a resampling procedure whenever *t* would be standard, as a check that the data allowed use of *t.* This left me with a greatly increased respect for the robustness of *t* with real data.

So although introducing inference via resampling makes the reasoning more accessible, it is not clear to me how to teach introductory statistical methods to a broad audience with inference based solely on resampling. Experimentation is needed and is no doubt underway.

JD: Thanks, David. SCC and IPS were first published in 1979 and 1989, respectively; both are still widely used today. Both books were certainly innovative when they first appeared, but both have gone through multiple editions in the past two or three decades. What are the most important ways in which the books have evolved over the years?

DM: The scope and sequence of the texts has remained quite stable, with some evolutionary changes that I hope are improvements. *SCC*, for example, has gradually increased the attention paid to hands-on data analysis. Lack of such attention is, I think, the chief weakness of the excellent FPP text mentioned earlier. *IPS* has seen some important responses to continuing research, particularly work demonstrating the sometimes wild inaccuracy of the standard confidence intervals for population proportions based on the asymptotic normal distribution of $\hat{p}$. Computer studies by Agresti and his students (Agresti and Coull 1998; Agresti and Caffo 2000), followed by comprehensive theoretical analysis by Brown, Cai, and DasGupta (2002) made it clear that the standard confidence intervals should be used only for very large samples. The fifth edition (2006) of *IPS* therefore introduced the "plus four" estimate of a population proportion and confidence intervals based on it. Agresti's work had shown that this simple device greatly improves the accuracy of the intervals. (There are yet more accurate procedures, but they are too complex for hand calculation and have not been incorporated in common software packages.) It disturbs me a bit to see the standard intervals still used in texts for the modest sample sizes common in scientific studies. They are in practice reliable only for the larger sample sizes typical of e.g. opinion polls – but of course these larger samples are rarely simple random samples!

I did collaborate with Tim Hesterberg on a supplementary chapter for *IPS* titled "Bootstrap methods and permutation tests." Tim is a real expert on these topics. This was an attempt to act on my belief that randomization procedures have a place in first courses. The chapter has been little used, perhaps because of software issues. Some of the few people who have read it consider it a clear introduction.

An important evolution in the *IPS* family was the appearance of *The Basic Practice of Statistics (BPS)* in 1995. *IPS* seemed to me after extensive teaching to be a bit difficult for typical non-major undergraduates. *BPS* attempts to present similar material with a similar conceptually rich approach, but with careful attention to accessibility. Relative to *IPS*, the chapters are more

numerous and considerably shorter, trains of thought are more concise, and there are frequent stopping points with a few straightforward "Apply Your Knowledge" exercises after each major new idea or procedure. Frequent stopping points is a key technique in helping students keep going. This is, by the way, a challenge in designing online or other electronic texts. How often when things get tough in a physical textbook do you look ahead and say "Ah, only a page and a half to go" in a section? Electronic media need to make equivalent relief possible. I would say that *BPS* represents my best attempt at an introductory text in statistical practice for undergraduates in less-quantitative disciplines, because of its careful attention to pedagogy as well as content.

As you might guess, my texts have now passed out of my hands, though my name will no doubt remain on them long after I am dead. For example, the last edition of *IPS* in which I was actively involved was the fifth. This appeared early in 2005, with a 2006 copyright. I held on to *BPS* longest, but the new sixth edition was prepared by the very capable Bill Notz and Mike Fligner. I make it a practice not to inspect the work of my successors, so I can't comment on any recent changes in "my" texts.

AR: What are your thoughts on the publishing industry in general today? Do you think that online resources and so-called "open" (freely available) textbooks are making business difficult for publishers of traditional print textbooks? Where do you see the publishing industry heading?

DM: I am reminded of an occasion a few decades ago when I heard an editor quite seriously claim that the used textbook business was under the control of organized crime. That is a useful reminder that all is not black for publishers – in the past, publishers (and authors) derived income from only the first of the three or four students who successively used a textbook copy. This is a major factor in the seemingly outrageous prices of hardcopy texts, and it is easy to see the vicious circle operating. Electronic texts are generally time-limited, so it is much more likely that three students in three consecutive terms will each pay for their own access.

I am of course not at all expert in the triumphs and tragedies of publishers. Some issues seem obvious (and some apply to trade books as well as texts). What is the graphical quality of the presentation? What kind of publicity will bring the book to the attention of potential readers or (for texts) potential adopters? Is an open text a labor of public service by a real expert, or essentially a local work by a semi-expert? Is an open text accompanied by the panoply of auxiliary material that publishers now make available online?

There are clearly superb open texts – consider, for example the *Princeton Lectures in Analysis* by Stein and Shakarchi (2003a, 2003b, 2005), widely available in pdf form online. This is a useful example: the texts, though intended for mathematics undergraduates, are quite difficult; their senior author is one of the world's great mathematicians and also famed for clarity of exposition. Stein's reputation is adequate publicity among professors of mathematics, and students up to the challenge will not be turned off by unadorned LaTeX or the lack of helpful auxiliary material. My uninformed guess is that open texts for (say) introductory statistics will have more difficulty in the market. And of course there is no longer such a business as "publishers of traditional print textbooks." Almost all introductory texts are in some way "mixed" print and online even if the print version still dominates use.

ASA Presidency

AR: You served as President of the American Statistical Association (ASA) in 1998. What did you learn about our profession, and about ASA, from that experience?

DM: Variety. I visited some 25 ASA chapters, and was impressed by the variety among them. The Albany chapter, for example, functioned effectively as a peer group and support system for statisticians working in many different New York State government agencies. Other chapters were strongly biomedical in emphasis, yet others academic, and of course some a vital mix. We often don't think much about the chapter system, but it gives ASA an adaptable local presence. I was also impressed by the willingness of ASA members to do committee service, rarely exciting but in aggregate vital. And I want to mention (and thank) Ray Waller and Jon Kettenring. Ray arrived as Executive Director at a time when "ASA central" was in some disarray and did a great deal in his straightforward and non-charismatic manner to straighten us out. Jon Kettenring, my predecessor as President, dealt calmly with every contingency and was an outstanding example of patient leadership. He probably doesn't know that I thought of him as "Saint Jon."

The personal highlight of my term was two dinners with Senator Daniel Moynihan, who agreed at the urging of (guess who?) Fred Mosteller to be my presidential invited speaker. Ray Waller reported with glee the envy of much larger scientific societies over our coup in attracting Senator Moynihan, and dinner conversation with the Senator, Jon, and a few others was more than worth the several bottles of very good Bordeaux that I paid for.

AR: You beat me to the punch: The next question I had in mind was about Senator Moynihan. Can you tell us about his qualities that made him such a sought-after speaker among scientific societies? And what did you discuss at dinner?

DM: Senator Moynihan was perhaps the outstanding public intellectual of his time, with an unusually varied and successful career. His opinions were strong, well-founded in data and evidence, and expressed forthrightly. His letters and essays remain very worth reading. At dinner, he wanted to hear more about the 2000 Census, then in preparation and a locus of some political controversy. He was among statisticians (though not among Census experts) and always looking for insights. And we did discuss some politics.

AR: One more question about your ASA presidency: Your Presidential address was titled "Statistics Among the Liberal Arts," (Moore 1998) and you have always (I believe) included a "To the Teacher" preface in SCC that is titled "Statistics as a Liberal Discipline." Can you summarize for us how you came to this view of statistics and why you feel strongly enough that you chose this theme for your Presidential address?

DM: A "liberal art" is now generally thought of as "a flexible and broadly applicable mode of thinking." That is, the liberal arts supply essential intellectual tools rather than a fixed cultural content. (This has not always been the case, as I point out in the address you cite.) The rigorous deductive method of mathematics qualifies, as does the interplay of observation and theory in the

natural sciences. So also do such humanistic skills as the interpretation of texts and the parsing of an artist's visual representation of reality and expression of her inner being. Statistics belongs in this company. None of the more traditional liberal arts incorporates the statistical mode of reasoning about data, variability, and chance, and none is more widely applicable to our lives as individuals in society.

I cannot recall a time when I was not interested both in the humanities and in science. As a schoolboy I enjoyed the *Iliad* as well as *Sky and Telescope*. Princeton taught me some math, but also a continuing love for German romantic poetry. I even considered switching to the history of science for graduate study. So when almost by chance I ended up in statistics, it was inevitable that as I understood the subject better I would begin to conceive it as a mode of thinking rather than as a purely technical discipline. Developing the course for liberal arts students that became *SCC* helped, as did participation (as a university ringer) in SLAW, a group of statisticians from selective liberal arts colleges. As for the theme of my Presidential address, well, these addresses are almost always broad in scope and completely non-technical. If the shoe fits, wear it.

Pop Quiz

AR: Now we begin what I'll call the "pop quiz" segment of the interview, where I'll ask very specific questions and will ask you to limit your responses to 2-3 sentences per question. First, what hobbies do you have outside of statistics and education?

DM: I read a lot, try to learn new things (I could tell you about trying to figure out quantum mechanics ...), travel, attend concerts (especially operas), watch the NBA, garden a bit, … Nothing very interesting.

AR: Okay, I have to ask: Tell us about trying to figure out quantum mechanics.

DM: Well, I don't mean *understand* quantum mechanics (if anyone does), but at least grasp the mathematical structure and attempt to see what is in the math and what is interpretation. It's impossible from non-technical sources to figure out just what the "Copenhagen interpretation" is, for example, as they differ quite a bit. The first thing I learned browsing in the physics library is that undergrad QM texts seem to concentrate on solving the time-independent Schrödinger equation in multiple simple settings. Not much enlightenment there, and in retirement I hope never to solve a differential equation. I finally discovered Bowman, *Essential Quantum Mechanics*, a book aimed at undergraduate physics majors and also at "people who are fascinated by quantum physics, but find the popularizations too simplistic, and the textbooks too advanced and comprehensive." That fit. Moreover, Bowman emphasizes that QM calculations give us probability distributions for measurements (understood in the ordinary frequentist manner) and nothing more. It's a good book and it helped a lot.

AR: You mentioned watching the NBA; which is your favorite team, and who is your favorite player?

DM: I watch basketball as an aesthetic experience rather than as a fan of a specific team. The San Antonio Spurs do the best job of playing basketball the right way. Even when their bench

players are in, the ball moves, the offense flows, the defense rotates. The entire team seems to be a single organism. The tone is set by Tim Duncan, the superstar without an ego and at age 37 still a very good player. That said, any lover of basketball will want to watch LeBron James, a member of some more highly evolved species both in his physical skills and in his basketball intelligence.

AR: What are 1-3 books that you've enjoyed reading in the past year?

DM: Kahneman, *Thinking Fast and Slow* was more than a year ago, but is so good it has to be mentioned. This year, Abate and Parker, *A History of Opera* and Hansen, *The Silk Road* come to mind among many others.

AR: Please tell us a bit about your family.

DM: A beautiful Korean-American girl persuaded me to ask her to the Junior Prom our senior year in high school (January 20, 1958). Neither of us had ever dated, and neither of us ever dated anyone else. We married six years later, after Nancy had completed her education. Our son Matthew is an engineer, married to an engineer. Our daughter Deborah is a musician, married to a musician. They each have two children, one of whom has more mathematical ability than I do (though his school is trying to make him lose interest).

AR: Name something that JSE *readers will probably be surprised to learn about you.*

DM: When *IPS* was published, Sol Garfunkel (head of COMAP) and I made a bet. Not seeing much correlation between my assessment of text quality and market success, I thought *IPS* would sell poorly. Sol thought it would sell well. We each chose an annual sales number, split the difference, and waited. The payoff was dinner for four at a restaurant of the winner's choosing anywhere in the world (travel not included). Sol enjoyed 18 annual dinners at the world's best restaurants at my expense.

AR: What a terrific story! Speaking of seeing the world, what are 2-3 of your favorite places that you have traveled? Perhaps you could mention one place that you've traveled for professional reasons and one that was purely for pleasure.

DM: We love France and Italy, always for pleasure. On business, I have been to a number of places that everyone should visit once: China, Malaysia, and New Zealand stand out, in part because I was three weeks or more in each. Imagine California with a population of a bit over 4 million and the world's friendliest people: that's New Zealand.

AR: Let's stick with a travel-related theme for the most fanciful question of the interview: Imagine that you can have dinner for four with anyone you'd like, anywhere in the world. Who would you invite, and where would you go?

DM: Nancy and I have long been fans of the great Paris restaurant Taillevent, site of the first "bet dinner" in 1990. Four is too few unless all are good friends, and I'm not up to trying to impress the rich and/or famous over dinner. So I will stretch it to six and invite our children and

their spouses. There are few joys to match seeing your kids grow up to be accomplished and responsible adults with whom conversation is a pleasure.

AR: What was your favorite course to teach?

DM: Statistical methods, from *IPS*, for Ph.D. students in non-quantitative disciplines. The students arrived in mortal fear. Many had taken a stat course as undergraduates and had understood nothing. But they were adults who wanted to learn and were willing to work. They did work and they did learn. That *IPS* opens with data analysis was a blessing: they could do this, the practical usefulness of the material was clear to them, and their fearful inhibitions melted away. They even learned SAS, which equipped them to talk with our consulting service when thesis time came. Most stayed for the second course, for which there was then no remotely suitable text (*STAT2* would now serve well). They thought I was wonderful, and I thought the same of them.

AR: Thanks very much for taking the time to answer all these questions with such thoughtfulness, David. Jackie will ask the final question.

Parting Thoughts

JD: I'd like to add my thanks for the time you've spent sharing your insights with us, David. Participating in this interview with you was a very special way to celebrate the 20th anniversary of JSE*. I'll close with Allan's usual final question: What advice do you have for* JSE *readers who are fairly new to statistics education?*

DM: Earlier interviewees, asked this same question, have offered similar sound advice: look at the available resources and in particular meet and interact with others who share your interest in teaching statistics. I can add little to this, so let me take a different tack.

Start with a critical look at your own teaching. Remember the classroom basics: talk to the class, not to the board; move around, project your voice, make eye contact; ask lots of questions (and wait 30 seconds). Next, think about adding new classroom behavior: small group problem solving sessions and minute papers ("What was the least clear point in this class?") are good places to start. Now go back and examine the overall design of your course. What do you really want your students to take away? Does your course structure reflect these emphases? Is the structure clear in advance to your students, so that they know roughly what is coming? Do your exams focus on the major points? And don't disregard your student evaluations. There's a lot of information there.

As you read and interact and gain experience, as your mastery of the craft of teaching advances, keep repeating this critical examination. Our goal, after all, is not to become savants of statistics education but to more effectively help our students learn.

References Cited in the Interview

Agresti, A. and Coull, B. (1998), "Approximate is Better Than 'Exact' for Interval Estimation of Binomial Proportions," *The American Statistician,* 52, 119-126.

Agresti, A. and Caffo, B. (2000), "Simple and Effective Confidence Intervals for Proportions and Differences of Proportions Result from Adding Two Successes and Two Failures," *The American Statistician,* 45, 280-288.

Brown, L., Cai, T. and DasGupta, A. (2002), "Confidence Intervals for a Binomial Proportion and Asymptotic Expansions," *Annals of Statistics,* 30, 160-201.

Cannon, A., Cobb, G., Hartlaub, B., Legler, J., Lock, R., Moore, T., Rossman, A. and Witmer, J. (2013), *STAT2: Building Models for a World of Data*. New York: Freeman.

Cobb, G., Garfield, J., Meeker, W. and Moore, D. (1995), "Statistics Education Fin de Siècle," *The American Statistician*, 49, 250-260.

Cobb, G. and Moore, D. (1997), "Mathematics, Statistics, and Teaching," *American Mathematical Monthly,* 104, 801-823.

Cobb, G. and Moore, D. (2000), "Statistics and Mathematics: Tension and Cooperation," *American Mathematical Monthly*, 107, 615-630.

Dempster, A. (1971), "Model Choosing and Estimation in the Logic of Inference" in *Foundations of Statistical Inference,* ed. V. Godambe and D. Sprott, Holt, Rinehart, and Winston (pp. 56-81).

Freedman, D., Pisani, R., and Purves, R. (2007), *Statistics* (4th ed.), New York: W. W. Norton & Company, Inc.

Hotelling, H. (1940), "The Teaching of Statistics," *Annals of Mathematical Statistics*, 11, 457-470.

Moore, D. (1988), "Should Mathematicians Teach Statistics?" *College Mathematics Journal*, 19, 3-7 and 32-34, with discussion.

Moore, D. (1995), "The Craft of Teaching," *MAA Focus*, 15, Number 2, 5-8.

Moore, D. (1997a), "Bayes for Beginners? Some Reasons to Hesitate," *The American Statistician,* 51, 254-261 and 272-274 (with discussion).

Moore, D. (1997b), "Bayes for Beginners? Some Pedagogical Questions," in S. Panchapakesan and N. Balakrishnan (eds.), *Advances in Statistical Decision Theory*, 3-17. Boston, MA: Birkhäuser.

Moore, D. (1998), "Statistics Among the Liberal Arts," *Journal of the American Statistical Association,* 93, 1253-1259.

Moore, D., McCabe, G., and Craig, B. (2012), *Introduction to the Practice of Statistics* (7th ed.). New York: Freeman.

Moore, D. and Mosteller, F. (1993), "A Generation of Statistics Education: An Interview with Frederick Mosteller," *Journal of Statistics Education*, 1.

Moore, D. and Notz, W. (2013), *Statistics: Concepts and Controversies* (8th ed.), New York: Freeman.

Moore, D., Notz, W., and Fligner, M. (2013), *The Basic Practice of Statistics* (6th ed.), New York: Freeman.

Soltner, A. (1995), quoted in *The New York Times*, 21 June 1995.

Stein, E. and Shakarchi, R. (2003a), *Princeton Lectures in Analysis I, Fourier Analysis: An Introduction*. Princeton, NJ; Princeton University Press.

Stein, E. and Shakarchi, R. (2003b), *Princeton Lectures in Analysis II, Complex Analysis*. Princeton, NJ; Princeton University Press.

Stein, E. and Shakarchi, R. (2005), *Princeton Lectures in Analysis III, Real Analysis: Measure Theory, Integration, and Hilbert Spaces*. Princeton, NJ; Princeton University Press.
